

## Validation of an Advanced High Pressure PEM Electrolyzer and Composite Hydrogen Storage, with Data Reporting, for **SunHydro** Stations

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*Principle Investigator*



**5/16/2013**

**2:45:00 PM**

**Crystal City Marriott**

**Project ID #  
TV020**

# Overview

## Timeline

*Project start date: Dec 2012*  
*Project end date: Sep 2015*  
*Percent complete: 12%*

## Budget / Funding

**\$ 1,400,000 total DoE share**  
**\$ 1,420,397 total cost share**  
***FY12 Funding : \$ 0***  
***FY13 Funding : \$1,196,763***

## Targets/Barriers

- **\$2.00-\$4.00/gge (2007\$)**
- **Hydrogen Storage**
- **Codes and Standards**
- **Lack of current H<sub>2</sub> Refueling Infrastructure Performance and Availability Data**

## Proton's Partners / Collaborators / Interactors

**Air Products & Chemicals - *Composite Storage / control - Supplier***  
**SunHydro LLC - *Fueling Stations - Collaborator***  
**Toyota Motor Sales - *FCHV Vehicles - Interactor***

# Relevance

## Target / Barriers

## Proton team Project Goals

**\$2.00-\$4.00/gge**

### Advanced PEM MEAs: (SH#1)

***Save Up to 8 kWh/kg H<sub>2</sub> - Ph. 2 Go/No-go***

- 57 bar H<sub>2</sub>, ambient O<sub>2</sub>
- In full-scale 65 cell stack, electrolyzer

***Compared to commercial 30 bar PEM***

### Adv. 57 bar PEM water electrolyzer (SH#1)

***Save up to 3.6 kWh/kg H<sub>2</sub> - Ph. 2 Go/No-go***

- H<sub>2</sub> gas drying purge loss
- Station mechanical compression to 70MPa

***Compared to 30 bar H<sub>2</sub> supply***

## Hydrogen Storage

### Adv. composite H<sub>2</sub> storage (SH#1 and #2)

***Double useable storage per unit volume***

- Cycle from 28 to 87MPa

***Compared to first generation storage tubes***

# Relevance

## Target / Barriers

## Proton team Project Goals

### Codes and Standards

#### Compact Component Arrangements:

*Fit SH#2 station within 12m ISO container*

- Safety and NFPA 2 code analysis
- Novel component arrangements
- Classified, non-classified zones
- Cooling, power, CSD, H<sub>2</sub> generation

*Speed AHJ approval, reduce install cost*

### Lack of H<sub>2</sub> Refueling Infrastructure Performance and Availability Data

#### Collect and report SH station performance

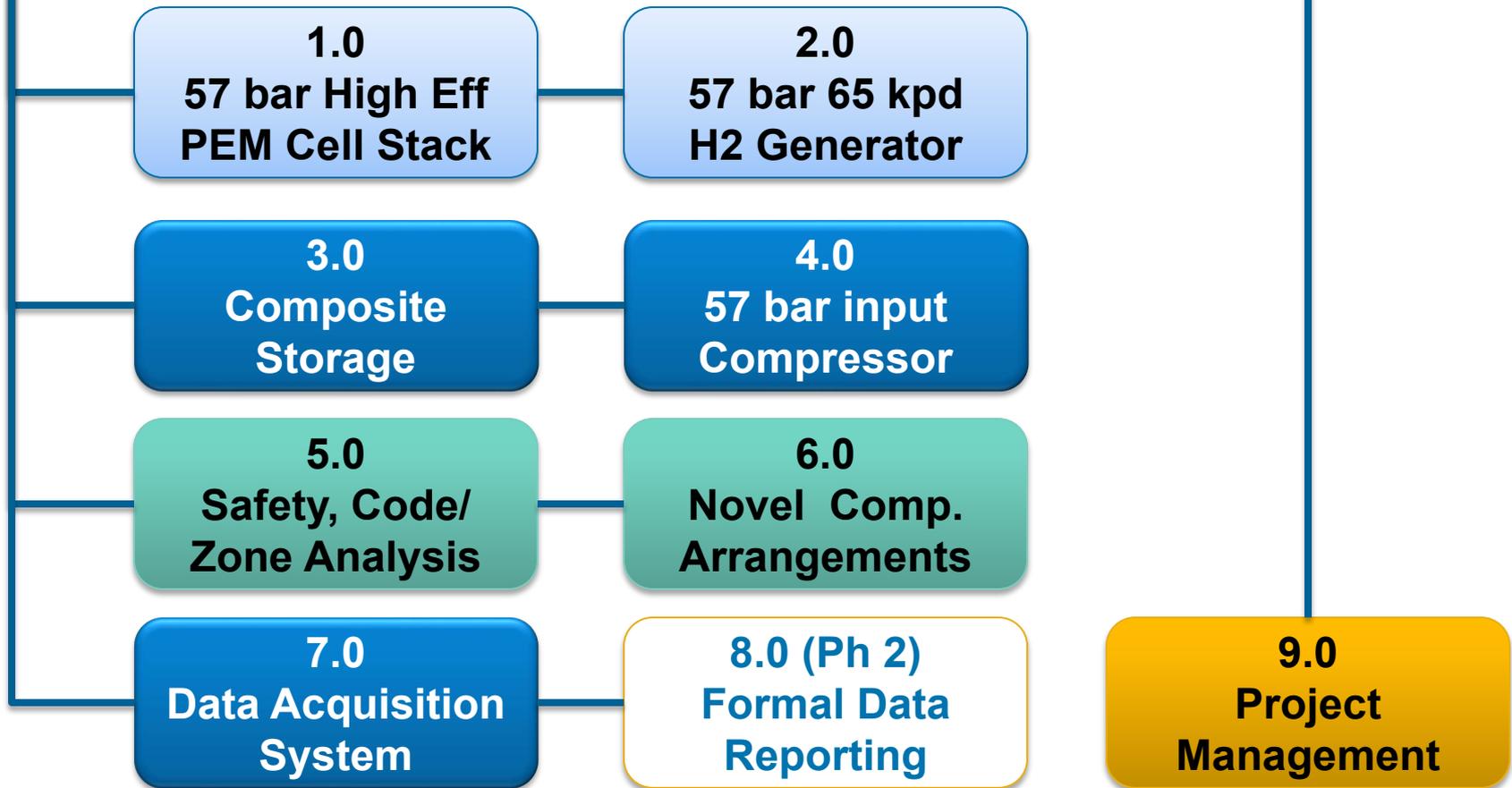
*Validate advanced technologies reliability*

- SunHydro #1 station, SunHydro #2 station
- Energy use, # fills, kg dispensed, capacity
- Maintenance type and frequency, issues
- “%Uptime”, any safety or customer issues

*Up to 24 months of station data*

# Approach

## Fueling Tech Validation Tasks



# Approach

1.0

## 57 bar High Eff PEM Cell Stack

Build adv. full-scale 65 cell stack

- advanced thinner PEM membrane
- advanced screened electrodes
- 57 bar mechanical design - latest production methods (from subscale)

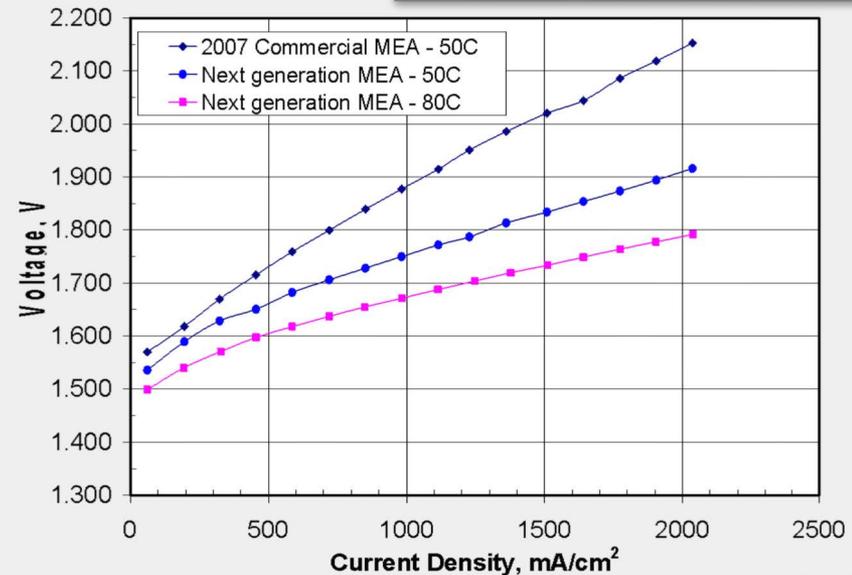
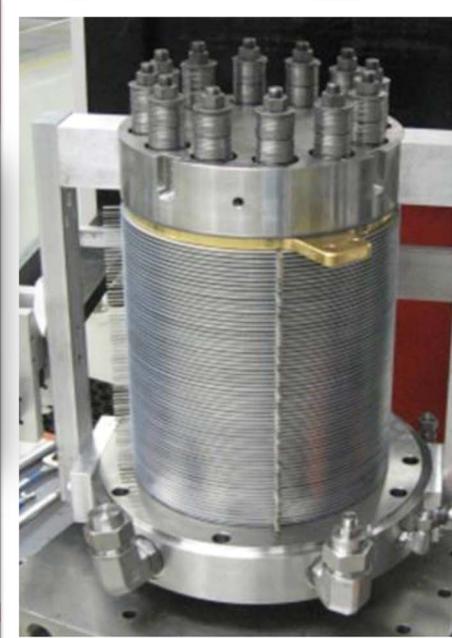
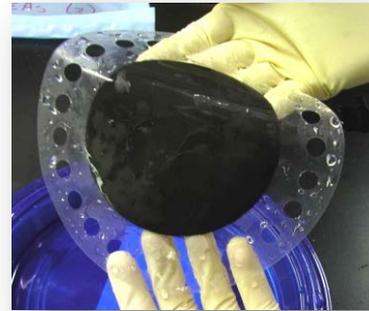
Validate mechanical integrity

- 57 bar  $H_2$  operating; 1.5x proof

Validate voltage reduction

- < 2.1, **goal** of 1.85 v/cell

**Goal:** up to 8 kWh/kg  $H_2$  savings vs. 30 bar commercial model



# Approach

2.0

## 57 bar, 65 kg/d H<sub>2</sub> Generator

### Build 30 bar baseline generator

- At SunHydro #1

### Upgrade H<sub>2</sub> gas components

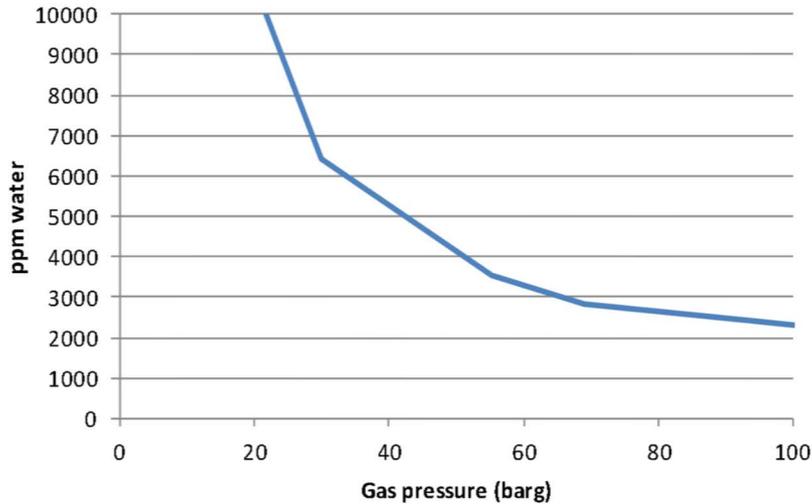
- 30 bar to 57 bar, 1.5x proof

### Make 65 kg H<sub>2</sub>/day at 57 bar

- Three (3) 57 bar cell stacks
  - Advanced cell stack
  - Two older 57 bar stacks

**Goal:** Approach 50% less purge loss\* with 57 bar generation vs. 30 bar operation

\* Swing bed regeneration



# Approach

## 3.0 Composite Storage

- **Upgrade/new storage systems, SunHydro#1 and #2**
    - SunHydro#1 : add 3 new 280 / 870 bar H<sub>2</sub> composite storage tubes to 6 existing 630 to 870 bar tanks
    - new installation for SunHydro#2
  - **Validate 280 - 870 bar operation, SunHydro#1 and #2**
- Goal:** *SunHydro#1 dispensing capacity increase ~16 kg/hr to about 30 kg/hr, with only 50% increase in tubes*



# Approach



4.0

## 57 bar input Compressor

### Perform differential compressor comparison

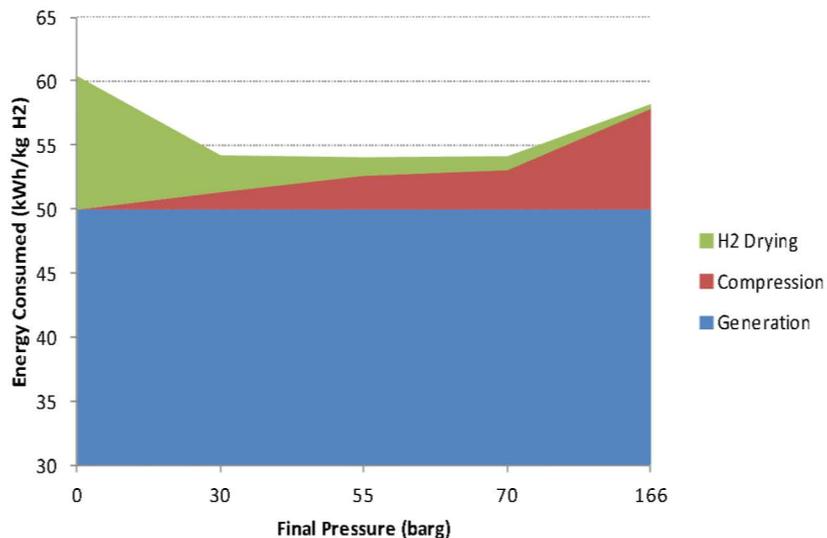
- Adjust SunHydro#1 compressor to accept 57 bar input
- 57 bar input to 30 bar on SunHydro#1 and #2

**Goal: kWh/kg reduction**

**Goal: kg/h increase**

*SunHydro#1 mechanical compressor can accept input from 21 to 57 bar, while SunHydro#2 is a 30 bar input model*

Electrolysis System Energy Use



# Approach

5.0

## Safety, Code/ Zone Analysis

- Review/update hazard evaluations for station upgrades
- Author safety operations plan
- Diagram EX zone reduction using code-informed compact component arrangements
- Participate in NFPA 2 revisions

6.0

## Novel Comp. Arrangements

- Non-EX electrolyzer adjacent to EX-rated CSD, in 12m ISO container
- Lightweight 2 h firewalls to demise
- Power, control, thermal in non-EX

**Goal: 12m station package, reliable, maintainable, permitted**



# Approach

## Individual site summary

- Survey station information
- Dimensional layout, simple process flow diagram

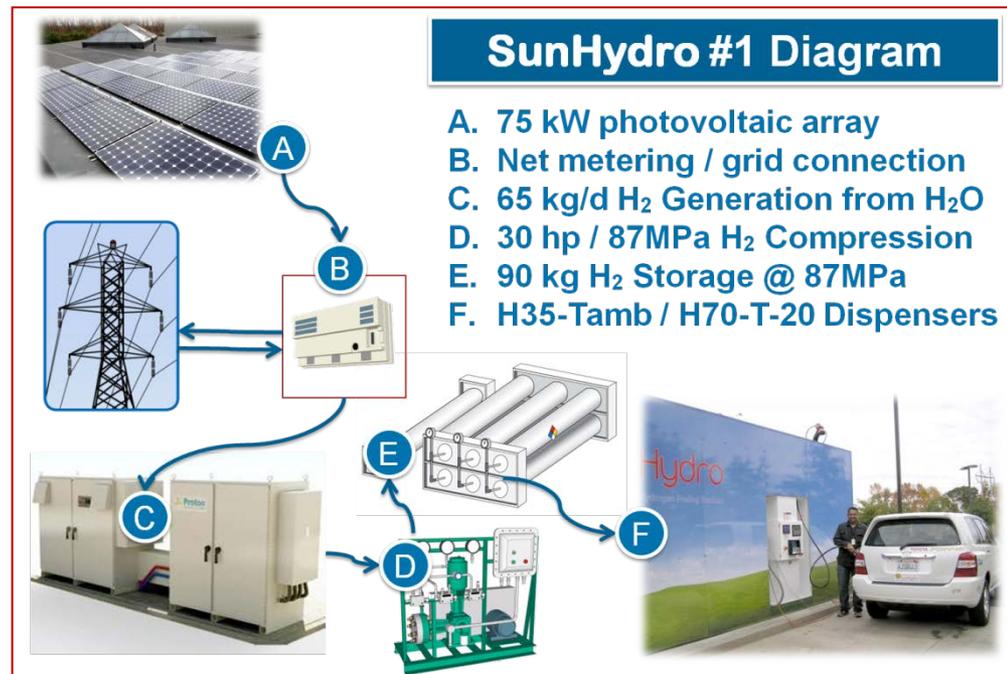
## Data collection plan

- Existing data acquisition – identify gaps
- Modifications and additions

## Station instrumentation install, SH#1, SH#2

- Monitor specific loads and operational status of each H<sub>2</sub> production, compression, storage, dispensing subsystem

## 7.0 Data Acquisition System



# Approach

## 8.0 (Phase 2) Formal Data Reporting



**Report collected SH#1 and #2 Station data using H<sub>2</sub> Refueling Station Templates to Hydrogen Secure Data Center at NREL.**

**Quarterly reports: (up to 24 months)**

- H<sub>2</sub> : kg produced, stored, dispensed, SAE J2719 quality, and costs
- Energy: kWh/kg for production, compression, dispensing
- Station reliability, maintenance, repairs, service data, and costs
- Station Safety incidents, near misses and hydrogen leaks

SunHydro #1  
- 2010 -



SunHydro #2  
-2013-



# Accomplishments and Progress

task	Description	Mar 2013 Progress
1	57 bar High Eff PEM Stack	<i>Materials ordered for Aug 2013 assembly New MEA Tooling ordered</i>
2	57 bar 65 kg/d H <sub>2</sub> Generator	<i>Baseline Generator built 57 bar upgrade in process</i>
3	Composite Storage	<i>Storage ordered for Sep 2013 commissioning Construction planning underway</i>
4	57 bar input Compressor	<i>Compressor design confirmed for 57 bar</i>

- Long lead materials and services ordered
- Build, test during 2Q,3Q 2013

# Accomplishments and Progress

task	Description	Mar 2013 Progress
5	Safety, Code/ Zone Analysis	<i>NFPA 2 revisions underway</i>
6	Novel Comp. Arrangements	<i>Design in process for SunHydro#2 arrangements</i>
7	Data Acquisition System	<i>Data survey , simple diagram Ordered software changes to stations</i>
8	Formal Data Reporting	<i>Contingent on Phase 2 Go/No Go Expect data activity to start in 3Q</i>

- Station analysis and novel design underway
- Data Acquisition planning underway
- Anticipate Go/No-go Phase 2 in 3Q

# Collaborations



## SunHydro LLC - *Fueling Stations*

- *Owner of SunHydro#1 station in Wallingford CT and SunHydro#2 station in Braintree MA*
- *Cost share provider*



## Toyota Motor Sales - *FCHV Vehicles*

- *Provides 10 FCHV-adv cars used at SH#1 and #2*
- *No cost lease with SunHydro LLC*



## Air Products & Chemicals – *Storage/control*

- Supplier *of advanced storage, commissioning*
- Supplier *of programming and dispensing data services*

# Future Work

## *Balance Phase 1 Major Activity*

- 2Q Adv. Cell stack MEA tooling testing**
- 2Q Modifications for 57 bar to baseline Generator**
- 3Q Advanced PEM stack build, test \***
- 3Q 57 bar PEM water electrolyzer build, test \***
- 2-3Q Station analysis and novel design**
- 2-3Q Data Acquisition design and installation**
- 3-4Q SunHydro#1 storage commission, compressor test**
- 3-4Q SunHydro#2 arrangements, permitted, commissioned**

*\*Adv stack, 57 bar system eff. Go/No-go Phase 2*

## *Phase 2 Major Activity*

**4Q-1Q, onward Station Data Acquisition**

# Technical Task Schedule

ID	Task Name	Start	Finish	2012	2013			
				Q4	Q1	Q2	Q3	Q4
1	1.0 Adv. 57bar Stack V&V	2/15/2013	7/15/2013					
2	2.0 Electrolyzer 57bar 65kpd V&V	12/3/2012	7/26/2013					
3	3.0 Composite storage V&V	3/1/2013	9/13/2013					
4	4.0 Compressor Eff./Throughput 57bar	10/1/2013	10/28/2013					
5	Order Composite storage	3/27/2013	3/28/2013					
6	Commission Upgraded SH#1	9/18/2013	9/20/2013					
7	5.0 Safety Code/Zone Analysis	4/15/2013	8/30/2013					
8	6.0 Novel Component Arrangements	4/15/2013	9/27/2013					
9	Commission SH#2	10/15/2013	10/15/2013					
10	7.0 Data Acquisition Design/Install	3/15/2013	9/13/2013					
11	SH#1 DAQ install and test	6/3/2013	6/14/2013					
12	SH#2 DAQ install and test	9/2/2013	9/13/2013					
13	8.0 Formal Station Data Reporting	9/30/2013	9/30/2015					

# Project Summary

**Relevance:** Addresses DoE goal of <\$4/gge, MYPP barriers of H<sub>2</sub> storage, codes, and lack of station performance data

**Approach:** Validate H<sub>2</sub> fueling infrastructure performance gains of an adv. 57bar PEM water electrolyzer, next-generation 87MPa composite storage tanks, and skid-mounted compact refueling component arrangements with an updated SunHydro#1 station and a fully containerized SunHydro#2 station. Data reporting to 24 months both SunHydro stations with adv. components.

**Tech Accomplishments:** Baseline PEM electrolyzer built; cell stack long lead items ordered; SunHydro#1 and #2 advance storage ordered; SH#2 arrangements underway; SH#1 diagrammed

**Collaborations:** SunHydro LLC (stations), Toyota Motors (vehicles), APCI (supplier storage upgrade and programming)

**Future Work :** Perform adv. PEM stack build and test; 57bar electrolyzer upgrade, SH#1 storage upgrade, compressor test, SH#2 arrangement, data plan/instrumentation, data reports

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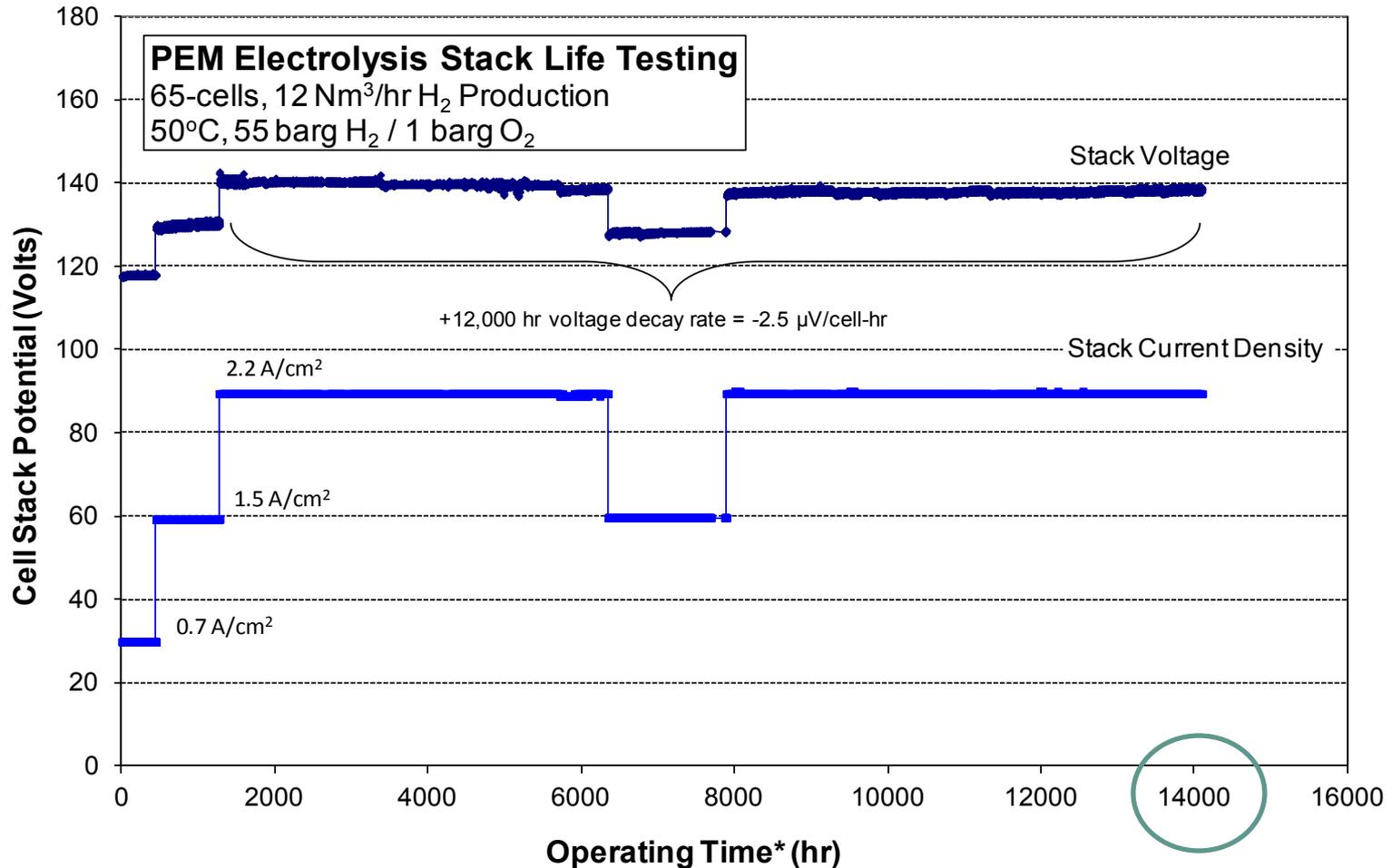
# Technical Back-Up Slides

# Proton® C Series PEM Electrolysis Stack

- **10 Nm<sup>3</sup>/hr stack for Navy Life Support Application in 2008**
  - 57 bar H<sub>2</sub> differential pressure
  - Over 1 million cell-hrs of validation
  - Currently in serial production
  - Over 18 months on-board submarines
- **Derivative 30 bar version in 2009**
  - Basis of C-Series 30 Nm<sup>3</sup>/hr commercial product design
  - Over 1.5 Million cell-hrs of customer field experience to date



# PEM Electrolysis Life Testing – ‘Mature’



\*Note: Non-operating time and restarts removed from graph



# SunHydro #1

## Operations

Jan 2011 – Mar 2013



~5800 kg of hydrogen dispensed

~1500 high pressure H2 fills

Serving fleet of 10 FCHV and paratransit

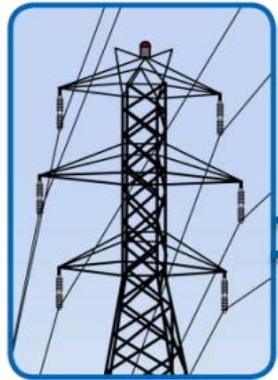


# SunHydro #1 Diagram

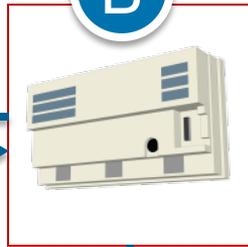
- A. 75 kW photovoltaic array
- B. Net metering / grid connection
- C. 65 kg/d H<sub>2</sub> Generation from H<sub>2</sub>O
- D. 30 hp / 87MPa H<sub>2</sub> Compression
- E. 90 kg H<sub>2</sub> Storage @ 87MPa
- F. H35-Tamb / H70-T-20 Dispensers



A



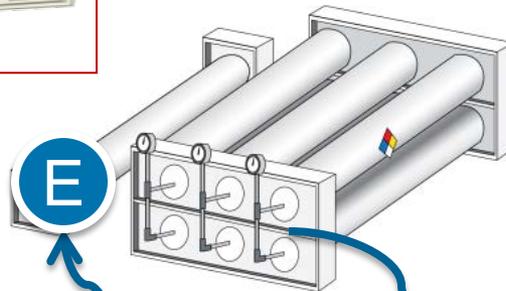
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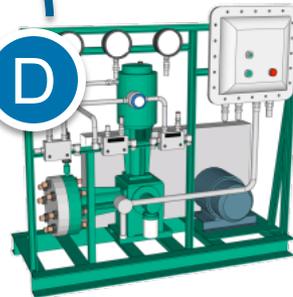
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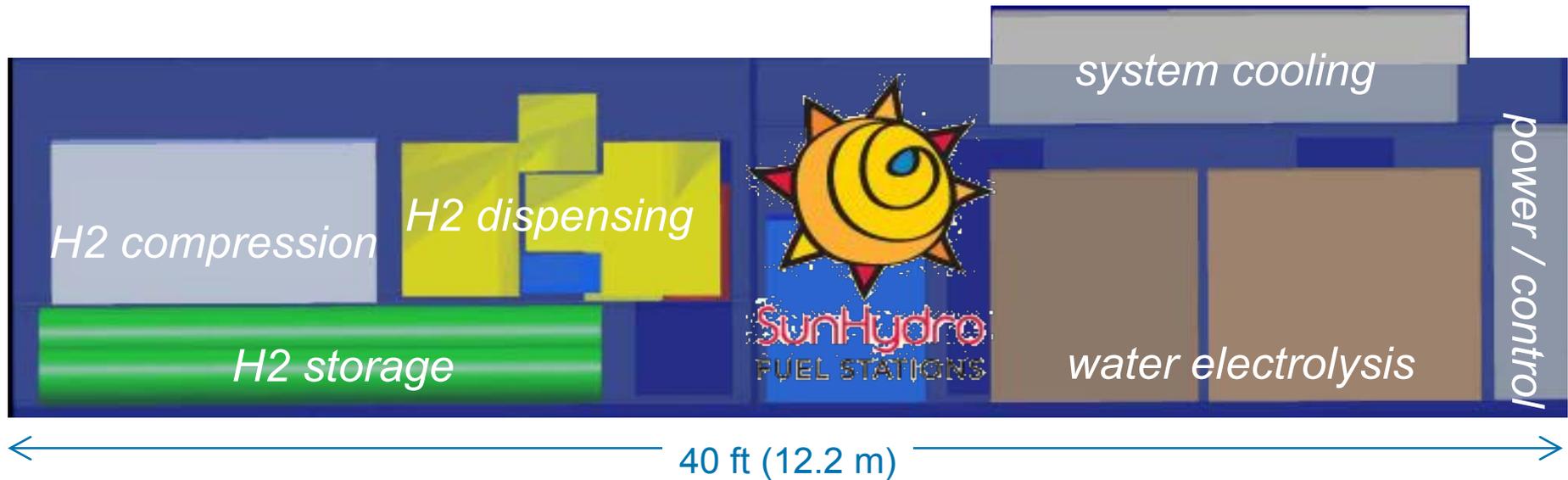


F



# SunHydro #2 Package Concept

- Total system in site-ready shipping container
- Aids serial manufacture, ease of deployment



**Challenge:** meet Code electrical clearances and performance with compact, practical arrangement

**Plan:** SunHydro commissions station Fall 2013